

## SMART LADDER

This application claims the benefit of U.S. Provisional Application No. 60/446,214 filed February 10, 2003.

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### BACKGROUND OF THE INVENTION

This invention relates generally to ladders that incorporate safety features, and more particularly to ladders that provide warnings to a user that the ladder is about to tip.

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Conventional household ladders (including step ladders and extension ladders) have enjoyed near universal acceptance by combining their ability to facilitate reaching remote areas with portable, human-carryable packaging. Nevertheless, conventional household ladders tip over when the combined center of gravity of a user (i.e., climber) and the ladder moves to a point beyond the foot of the ladder. In such a case a moment is produced, and while the frictional force of the wall tends to counter the torque caused by the moment, often it is not enough to prevent the ladder from tipping. Unbalance leading to ladder tipping typically occurs in one of two ways. In the first, the climber leans over too far to one side such that the center of gravity is beyond the ladder footprint. In the second, the ladder is placed leaning to one side, such as due to being placed on an uneven surface. In this latter case, the vertical line from the center of gravity of the ladder may not initially be beyond a foot of the ladder; however, as the climber moves higher up the ladder, the combined center of gravity of the ladder and the climber moves outside the ladder feet. Even though the imbalance leading to tipping of a ladder develops only gradually in this second instance, the climber remains unaware of the hazard until it is too late and the ladder tips over.

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Accordingly, there exists a need for improvements in ladder design to enhance ladder safety, especially as it relates to ladder tipping. Moreover, there exists a need for notorious warnings that can alert a ladder user that a dangerous operating condition is imminent. Furthermore, there exists a need for a ladder that can deploy additional stabilizing members in response to dangerous ladder operating conditions. In addition, there exists a need for such a

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ladder that provides the above while being inexpensive and without sacrificing its human-carryable attributes.

## SUMMARY OF THE INVENTION

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These needs are met by the present invention. According to a first aspect of the present invention, a ladder configured to be carried by at least one human user is disclosed. The ladder includes a plurality of legs and rungs, one or more weight sensors coupled to at least one of the plurality of legs or rungs, a controller signally coupled to the one or more sensors a tip warning system and a power source to energize at least the tip warning system. The tip warning system is responsive to the controller such that upon attainment of a predetermined signal threshold, at least one of an audio or visual alarm provides notorious indicia to the user.

Optionally, the ladder is configured such that the one or more weight sensors are disposed adjacent the first end. Furthermore, the one or more weight sensors are disposed beneath the first end such that when the first end is placed upon a ladder-supporting surface, the sensor (or sensors) can measure a weight imposed by the ladder (when no one is standing on it) or by the combined weight of the ladder and a user standing on the ladder. In one form, the predetermined signal threshold can be a sensed weight that falls below a predetermined minimum. For example, if the signal threshold is set such that a sensed weight reading of close to zero (or some other predetermined number) registers with the controller (which would indicate that the weight sensor in question is detecting a significantly reduced load corresponding to the predetermined number), then the tip warning system would activate to alert the user of the unstable condition. In another form, a plurality of weight sensors can be deployed on the ladder so that the predetermined signal threshold could either be the predetermined minimum weight reading as discussed above, or another parameter such as the difference or ratio between the plurality of weight sensors, where the difference exceeds a predetermined maximum. In this configuration, it is a weight differential (either in the form of a simple difference or a ratio of readings from the disparate sensors) that is the triggering signal rather than the absolute value of the single weight sensor configuration above. This could be used, for example, in conjunction with laterally-spaced weight sensors so that the onset of a side-to-side imbalance could be sensed

prior to such an imbalance becoming dangerous. The controller can be analog-based, utilizing comparator integrated circuits, or digital-based, using analog to digital (A/D) converters and a microprocessor.

5           The ladder may further include a movable counterbalancing weight responsive to the controller such that it deploys upon attainment of the predetermined signal threshold. At least one of the alarms can be disposed adjacent the second end. For example, where the alarm is a visual alarm (such as lights or a display, both discussed in more detail below), such an arrangement beneficially places the visual alarm relatively close to a user's eye such that early  
10 recognition of a potentially unsafe ladder operating condition is being approached. In yet another option, the power source can be a battery, solar cell or the like. Moreover, the ladder is preferably a household ladder, such as a stepladder or an extension ladder. As mentioned above, the visual alarm may be made up of one or more lights, where in the case of a plurality of lights, each of the plurality of lights corresponds to particular ladder safety category, such as a first  
15 safety category, a second safety category and a third safety category, or to a system operational status (for example, indicating whether the system is on or off). Similarly, the audio alarm can be one or more buzzers, a prerecorded verbal warning or the like. In the case of a buzzer, the alarm can be configured to emit tones of progressively higher frequency or volume as the ladder gets closer to an unstable, imbalanced position.

20           According to another aspect of the invention, a tip-sensing ladder is disclosed. The ladder includes a plurality of legs defined by a first end and a second end, a plurality of rungs disposed between the legs and a tip warning system. The system includes a plurality of weight sensors coupled to legs or rungs, a controller signally coupled to the weight sensors, a plurality  
25 of alarms comprising an audio alarm and a visual alarm, and a power source. The alarms are responsive to the controller such that upon attainment of a predetermined signal threshold in the controller, at least one of the alarms activates.

          According to still another aspect of the invention, a method of using a ladder is disclosed.  
30 The method includes configuring a ladder similar to that of at least one of the previously-described aspects, placing the tip warning system in an operational condition, placing the ladder

against a ladder engaging surface, climbing the ladder such that indicia is provided to a climber thereof to indicate at least one of an operational status or a ladder safety category. Optionally, the ladder safety category comprises at least two first ladder safety categories, where the first is indicative of no imminent tipping, while a second is indicative of a possible tipping condition.

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## **BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS**

The following detailed description of specific embodiments of the present invention can be best understood when read in conjunction with the following drawings, where like structure is indicated with like reference numerals and in which:

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FIG. 1 illustrates a ladder according to an embodiment of the present invention;

FIG. 2 illustrates a Wheatstone bridge circuit incorporating weight sensors R1 and R2;

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FIG 3A illustrates one form of visual display used to indicate the level of imbalance;

FIG 3B illustrates another form of visual display used to project a warning sign;

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FIG. 4 illustrates a modified Wheatstone bridge circuit incorporating the weight sensors R1 and R2;

FIG. 5 illustrates the circuit of FIG. 4 integrated with a quad comparator to sense ladder imbalance;

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FIG. 6 illustrates MOSFET logic using input from the comparator of FIG. 5 to control a plurality of colored lights and buzzers; and

FIG. 7 illustrates an optional counterbalance weight attached to the ladder of FIG. 1.

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## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring initially to FIGS. 1, 3A and 3B, a ladder **10** according to an embodiment of the present invention is shown placed on a ladder-engaging surface **5** (such as a floor, the ground or the like). Ladder **10** includes a pair of legs **12** each defined by a first end **12A** positioned on ladder-engaging surface **5**, and second end **12B** opposite first end **12A**, and a plurality of rungs **14** that connect the legs **12** together. It will be appreciated by those skilled in the art that while the embodiment depicted in the figure is a fixed household ladder, the present invention is equally suitable to extension ladders, step ladders, folding ladders or the like. In the present context, the phrase "household ladder" is not meant to limit applicability to ladders used in private, residential settings. As such, the phrase is understood to include commercial and non-residential variants, so long as the ladder is portable by being human-carryable, such as those that can be carried by an individual. Ladders that generally do not qualify as "household" or "human-carryable" are those that form an integral part of a larger structure, such as a ladder that is permanently or semi-permanently secured to a fire-engine or related safety vehicle.

Ladder **10** includes weight sensors **20**, controller **30** and one or more audio alarms **40** and visual alarms **50**, where visual alarm **50** is shown in one form as a series of lights **50A**, **50B**, **50C**. Visual alarm **50** can be made up of a series of lights, where the lights are color-coded. For example, a green light **50A** can indicate a first ladder safety category, while a yellow light **50B** can indicate a second ladder safety category (possibly coinciding with a condition requiring caution), and a red light **50C** to indicate a third ladder safety category (possibly coinciding with a dangerous operating condition with a significant amount of imbalance). Together, weight sensors **20**, controller **30** and alarms **40** and **50** make up tip warning system **60**, where tip warning system **60** can give the ladder "smart" features such that it can sense and convey to the user indicia of an impending dangerous operating condition faster than the user can.

Referring with particularity to FIGS. 3A and 3B, two variations on an alternate embodiment of the visual alarm is shown, where in the first variation of FIG. 3A, a meter **100** registers the degree of imbalance, while in a second variation of FIG. 3B, a warning display **200** responds to controller **30** by highlighting various words dependent upon the ladder safety

category (also known as the imbalance status), where the aforementioned first ladder safety condition is accompanied by a green color display **200A** of the word SAFE, a moderate amount of imbalance (commensurate with the aforementioned second ladder safety condition) is indicated by a yellow display **200B** of the word CAUTION, and a hazardous condition  
5 (equivalent to the aforementioned third ladder safety condition) indicated by a red display **200C** of the exclamation DANGER! as shown. Also as previously discussed, the hazardous condition could also be accompanied by an audible warning from audio alarm **40**.

Referring with particularity to FIG. 1, weight sensors **20** are placed at the bottom of each  
10 leg **12**. In a preferable form, the weight sensors **20** are of lightweight construction such that they do not appreciably add to the overall weight of ladder **10**. In one form, the sensors **20** are of the laminated thin-film variety, where the electrical conductance is substantially proportional to the applied force or weight upon them. In the present context, the term "substantially" is utilized to represent the inherent degree of uncertainty that may be attributed to any quantitative  
15 comparison, value, measurement, or other representation. As such, it refers to an arrangement of elements or features that, while in theory would be expected to exhibit exact correspondence or behavior, may in practice embody something slightly less than exact. The term also represents the degree by which a quantitative representation may vary from a stated reference without resulting in a change in the basic function of the subject matter at issue. Although shown with  
20 two weight sensors **20**, it is also within the scope of the present invention to configure the ladder **10** with a single weight sensor **20**, mounted at or near the first end **12A** of one of the legs **12**. As previously discussed, the sensors **20** can either be coupled so that they send a difference or ratio signal to controller **30**, or they can be independent, where each can respond to a predetermined weight threshold stored in the memory of controller **30**. For example, the stored threshold may  
25 be an equivalent to an absolute force value, such as something at or near zero pounds force, zero being the condition prerequisite on one of its legs **12** for ladder **10** tipping. By using weight sensors **20** rather than a conventional pendulum-based indicator, the present invention allows a more accurate reading to be taken, as the weight sensor (or sensors) **20** can account for user-generated moments that a pendulum-based or switch-based device would not be sensitive to.  
30 This additional sensitivity is possible because the tip warning system **60** of the present invention can discriminate against user weight on the lower rungs **14A**, as such condition is not as likely to

produce a tipping condition as that when the user is on the middle or upper rungs **14B**, **14C**. By contrast, a pendulum-based or switch-based device is responsive only to the angle the switch or pendulum registers relative to a predetermined axis.

5 Referring next to FIG. 2, a Wheatstone (or resistance) bridge type electrical circuit **36** was formed incorporating two weight sensors **20** that demonstrate variable resistance  $R_1$  and  $R_2$  and two fixed resistors **22** that demonstrate substantially fixed resistance  $R_0$ , where the imbalance between the sensor voltages provided a measure of the weight imbalance at the legs **12**. Battery **32** (for example, a conventional nine-volt battery) provides power to controller **30**,  
10 although it will be appreciated that other power sources could be employed, including, for example, solar cells or related photovoltaic devices. When equal weight is applied to both sensors **20**,  $R_1$  will equal  $R_2$  and the corresponding output voltages  $V_1$  and  $V_2$  will be equal. Contrarily, a weight imbalance on ladder **10** shows up as a difference between  $V_1$  and  $V_2$ . In the simplest system, output voltages  $V_1$  and  $V_2$  could be wired directly to meter **100**, as shown in  
15 FIG. 3A. In a preferred (but by no means necessary) system, the output voltages  $V_1$  and  $V_2$  will be further processed by either digital or analog electronics in controller **30** to provide a more reliable warning system. In one preferred embodiment, voltages  $V_1$  and  $V_2$  will be read by controller **30** that would include an analog-to-digital (A/D) converter and a microprocessor (not shown). The microprocessor will control the tip warning system **60** according to a program  
20 stored into its memory where, as previously discussed, the tip warning system **60** may include one or more of the aforementioned alarms, such as the lights **50**, meter **100**, display **200**, audio system **40** or some combination thereof. The measured values from the weight sensors **20** are then used to calculate the imbalance according to an algorithm and compared to a predetermined threshold. If controller **30** detects imbalance beyond the predetermined threshold, at least one of  
25 the audio and visual alarms **40**, **50** are activated to alert the user. Tip warning system **60** can be programmed such that the companion audio alarm **40** responds either progressively (with, for example, a loudness or frequency level that increases concomitant to the aforementioned ladder safety category) or selectively (for example, not until a predetermined threshold). The indicia enabled by audio alarm **40** is beneficial in that a ladder user need not constantly maintain line-of-  
30 sight contact with a visual alarm to be apprised of a potentially dangerous ladder **10** operating condition. The two separate forms of indicia made possible by combining audio and video

alarms **40, 50** further improves the chances that a user will be alerted that a potentially dangerous ladder operating condition has been, or is about to be, reached. Operational status of tip warning system **60** could be ensured by including a confirmation signal, such as a simple, slow-period (i.e., low frequency) beep from the audio alarm **40** or a slow-period flash of light from the visual alarm **50**.

Referring next to FIGS. 4 through 6, an approach to sensing and alerting a user as to the presence of a ladder imbalance is shown. Referring with particularity to FIG. 4, a modified Wheatstone bridge **80** incorporating the weight sensing resistors **20** (again capable of registering variable resistance  $R_1$  and  $R_2$ ) is shown. FIG. 5 shows how the various connections **a, b, c, d, e, f** and **g** of the Wheatstone bridge **80** of FIG. 4 are integrated with a quad comparator **90** to provide the imbalance triggers that are then fed into the controller **30** logic circuit shown in FIG. 6. While one way to operate the tip warning system **60** is to monitor in real time the weight on each leg **12** such that one or both of the alarms **40, 50** are activated whenever the sensed weight on either leg **12** falls below preset limits, it is more reliable and more independent of the user's weight to implement tip warning system **60** in the manner described next.

The construction of modified Wheatstone bridge **80** is such that two voltage divider chains **82, 84** comprise three resistors each. The first chain **82** includes resistors **R3, R4** and **R5** while the second **84** includes resistors **R6, R7** and **R8**. In one implementation, the resistors **R3, R5, R6** and **R8** are 10 kilo-ohms each, while resistors **R4** and **R7** are each a 22 kilo-ohms adjustable potentiometers. The resistor junctions **d, e, f** and **g** provide convenient reference voltages for comparator **90** to analyze the voltage appearing at the junction **b** between the weight sensors **20** (with the aforementioned variable resistances  $R_1$  and  $R_2$ , respectively). As shown in FIG. 5, the four comparator circuits **92, 94, 96** and **98** within comparator **90** were set up to compare the voltage appearing at junction **b** with that at junctions **d, e, f** and **g**, respectively. Circuit **91** is arranged with two pairs of comparators that are wired such that switch signals occur at points **A** and **B** at certain levels of ladder imbalance as the values measured by weight sensors **20** vary. The variable resistors **R4** and **R7** can be adjusted to select the levels of imbalance between weight sensors **20** at which **A** and **B** switch to a low voltage reading. By choosing resistor **R7** to be greater than resistor **R4**, point **A** is ensured to switch from a high voltage to a



low voltage before point **B** does. Initially, with weight sensors **20** being comparable in value, the output voltage at points **A** and **B** are both high. Analysis shows that point **A** stays high as long as  $(R3/(R4+R5)) < (R1/R2) < ((R4+R3)/R5)$  and switch to the low state outside this range (where **R1** corresponds to the weight sensor **20** located between points **b** and **c** in FIG. 4 and **R2** corresponds to the weight sensor **20** located between points **a** and **b**). With resistor **R3** chosen equal to resistor **R5** for symmetric switching, the magnitude of resistor **R4** determines the point at which point **A** would switch. The larger the value of resistor **R4**, the greater the imbalance between **R1** and **R2** required for the switch to occur. As an example, if **R3** = **R5** = **R6** = **R8** and **R4** is twice the value of **R3**, and **R7** is three times the value of **R3**, then point **A** would stay high for a ratio of **R1** to **R2** (or **R2** to **R1**, depending on which of the weight sensors **20** registers the larger load) less than three, and would switch to low when the ratio becomes greater than three. Similarly, point **B** will switch from high to low when the ratio of **R1** to **R2** (or **R2** to **R1** for the reason mentioned above) is greater than four. The switching of points **A** and **B** can be exploited to activate the audio alarm **40** and the lights **50A**, **50B**, **50C** or displays **100**, **200**, shown and described previously when a state of imbalance is approached or achieved.

Referring with particularity to FIG. 6, specific implementation of the embodiment of tip warning system **60** employing the series of lights **50A**, **50B**, **50C** is shown. The simplest logic implementation was achieved using four MOSFETs **52**, **54**, **56** and **58** as shown. The output from point **A** is connected to the gate of MOSFET **52** while point **B** is connected to the gate of MOSFET **56**. With points **A** and **B** registering high voltages, only the green light **50A** is turned on. When point **A** switched to a low voltage, the yellow light **50B** comes on while green light **50A** is turned off. With point **B** also switching to a low voltage (while point **A** stays low), the red light **50C** is turned on while yellow light **50B** is turned off. Audio alarm **40** connected in parallel with the lights **50A**, **50B**, **50C** can provide audio warnings. As previously mentioned, different sounds (or even different audio alarms **40**) can be used to give a user a distinguishable audible warning depending on the severity of the imbalance, where variations in tone, volume or any other easily-perceivable quantity can be utilized. In the case of tone variation, the audio alarm **40** can emit a slow beep or, alternatively, a low frequency signal for a first ladder safety condition, with progressively higher frequency signals for the second and third ladder safety conditions.

The attributes of tip warning system **60** hitherto described are of a passive nature; while the system **60** senses force values and reports possible ladder imbalance conditions, it does nothing to correct a potentially dangerous situation. Referring next to FIG. 7, ladder **10** may incorporate active tip-prevention features that utilize the imbalance information generated in the tip warning system **60** by deploying one or more members that are attached to the ladder **10**. In one form, the tip-prevention member is made up of one or more deployable counterbalancing weights **15**. These weights **15** can be released upon appropriate signal from controller **30** to motor **18** that drives a screw **17** that turns gear **16** to which weight **15** is attached. When user **1** leans too far to one lateral side of ladder **10**, sensors **20** detect the weight shift, causing controller **30** to activate motor **18**, screw **17**, gear **16**, which in turn causes deployment of counterbalancing weight **15** to the opposing lateral side of ladder **10**. In other configurations, the weight **15** could be spring-loaded or even manually adjustable.

Having described the invention in detail and by reference to specific embodiments thereof, it will be apparent that modifications and variations are possible without departing from the scope of the invention defined in the appended claims. More specifically, although some aspects of the present invention are identified herein as preferred or particularly advantageous, it is contemplated that the present invention is not necessarily limited to these preferred aspects of the invention.

What is claimed is: